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AUTHOR Kauffman, Sue Cox
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ABSTRACT

This teachers guide is designed to accompany a series of posters developed through the U.S. Geological Survey's Water Resources Education Initiative, a cooperative effort between public and private education interests. It provides teacher guidance, background information, suggestions for a variety of classroom activities, and supplemental resource lists, and offers a systematic framework for including water resources education into existing curricula and for applying this curriculum to emerging national standards. The posters treated in this volume include: (1) "Water: The Resource That Gets Used & Used & Used for Everything"; (2) "How Do We Treat Our Wastewater?"; and (3) "Wetlands: Water, Wildlife, Plants & People". Although designed for grades 3 to 8, these posters can complement water topics in any grade. (JRH)

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WATER MATTERS

WATER RESOURCES TEACHER'S GUIDE

VOL. 1

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National Science Teachers Association

Introduction

Getting Started

Most Americans can turn on a faucet and receive all the clean water they want. And most pour wastewater down their sinks and flush their toilets without a thought for the path that wastewater takes before it reenters nature's water cycle. Where does our fresh water come from? How is it used? How is it treated so that we may reuse it? How does water use affect our wetlands? These are just some of the topics developed in this series of water resources posters. This *Teacher's Guide* will help you maximize the impact those posters have. Inside, you'll find background materials, a wide range of activity suggestions, and supplemental resource lists, each designed to make teaching about water resources easy, constructive, and fun!

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About the Water Poster Project

This package includes a series of posters developed through the U.S. Geological Survey's *Water Resources Education Initiative*, a cooperative effort between public and private education interests. Nine topical posters are being created, each detailing one water theme. Individual themes are shown in Figure 1. (The shaded row indicates the posters included here.) On the reverse side of each poster is background material and at least one ready-to-use activity. To meet the different needs of elementary and middle level students, two versions of each poster are available.

An exciting part of these posters' design is their connectability. Each row fits together to create a mural. This design serves to remind us of the integral part water has in our lives and in our environment. The way water is used in one place affects its quality and supply far away. Hanging these posters together will help students see this larger picture. Too often students understand large systems only in terms of their parts: a faucet delivers a glass of water, lakes are used for swimming and fishing. But the faucet and lake are *interconnected* in the water resources system: the water in the glass might be coming from the lake! One goal of this poster series and the Water Resources Education Initiative is to reinforce this concept of interconnectivity.

Partners in the Water Resources Education Initiative include: National Science Teachers Association, U.S. Geological Survey, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, and The Groundwater Foundation.

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Biodiversity	Watersheds	Acid Rain or Hazardous Materials
Wetlands	**Water Use**	**Wastewater Treatment**
Oceans or Navigation	Ground Water	Water Quality

Figure 1

Subjects of posters in *Water Resources Education Initiative*. (Shaded row represents posters treated in this volume.)

How to Use This Teacher's Guide

This *Teacher's Guide* serves a variety of functions. It provides teacher guidance, background information, and suggestions for a variety of classroom activities. It offers a systematic framework for including water resources education into existing curricula and for applying this curriculum to emerging national standards. It provides a concrete example of integrated curriculum in science, with subjects from several disciplines taught at once. Most important, this *Teacher's Guide* will spark your imagination when designing lessons to make use of the water resources poster series.

Ultimately, three *Teacher's Guides* will be published for this series. Each will cover one of the rows shown in Figure 1. The posters treated in this volume include:

- "Water: The Resource That Gets Used & Used & Used for Everything!"
- "How Do We Treat Our Wastewater?"
- "Wetlands: Water, Wildlife, Plants & People!"

In the Classroom

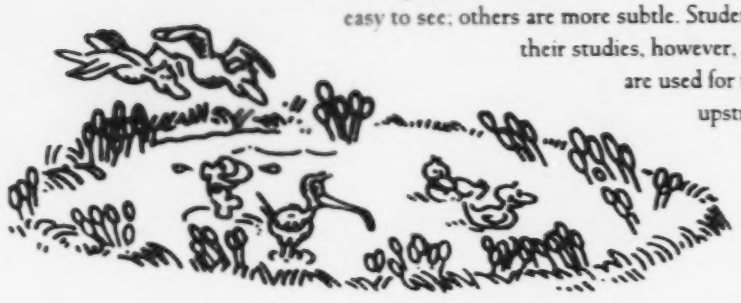
Although designed for use in grades 3 to 8, these posters can complement water topics in any grade. Ongoing efforts to reform science curriculum—including the National Science Standards, Project 2061, and the Scope, Sequence & Coordination project (SS&C)—make extensive use of water resources topics. This poster series can be integrated easily into such programs. For instance, content organizers for SS&C have emphasized human impact on the environment, surface water, and water quality in their outlines for teaching biological and hydrological processes. The emphasis on interconnectivity and systems assists teachers using materials developed by Project 2061. If you refer to your school's curriculum framework while reading this *Teacher's Guide*, you'll see other places and ways these materials can be used. And you'll see other connections: mathematics, language arts, geography, art, and music.

A Note About Photocopying

This package contains *two* versions of each poster. Although the front panels are identical, the backs are not. One version has background and ready-to-use activities for grades 3–5; the other, grades 6–8. Having two posters allows you to display one while cutting the other into sections for use in various activities. Laminating both the whole poster and the pieces will increase longevity; however, for future use, *make several copies and transparencies of each panel (front and back) before lamination.* Be sure to store a master copy.

Water: The Resource That Gets Used & Used & Used for Everything!

This poster is designed to improve your students' understanding of water's many roles in their daily lives. The highly visual format will stimulate student discovery and discussion. Some water uses are easy to see; others are more subtle. Students spot specific water uses first. As they continue their studies, however, students discover more subtle water uses (e.g., rivers are used for transportation) and larger-scale interconnections (e.g., upstream use affects downstream conditions). By introducing several distinctions you will encourage this discovery: some uses are *instream* while others are *offstream*; at the same time, water consumption can be either *direct* or *indirect*. These distinctions will be discussed below.



Where Does Fresh Water Come From and Where Does It Go?

We have a lot of water on this planet. Ninety-seven percent of Earth's water is found in our oceans. Of course, this is *salt* water. Most of Earth's *fresh* water is stored in ice caps and glaciers on Antarctica and Greenland. Other freshwater sources can be found on land surfaces (such as rivers, lakes, streams, and ponds), in underground reservoirs called aquifers, and as soil moisture, atmospheric water vapor, ice, and snow. Surprisingly, of all the water on and in Earth, *less than one percent* of its fresh water is readily available for human use!

An average 16 trillion liters of precipitation fall daily over the 48 contiguous states in the U.S. What happens to this daily precipitation is summarized in Data Box 1. Sixteen trillion liters a day—that's 5,840 trillion liters each year—is an enormous amount of fresh water. Nevertheless, students may misunderstand this statistic and think Americans generally have plenty of fresh water available to them. You can help avoid this misunderstanding by raising several points. First, not all the fresh water students see around them is clean. Second, not all the water that falls as precipitation is available for use by people. As shown in Data Box 1, two-thirds of what falls evaporates again and returns to the atmosphere. Third, precipitation patterns change over the seasons and are different across the different regions of our country. The 16 trillion liters number averages *all* forms of precipitation in every region of the contiguous 48 states over the *entire* year. Your students probably already know that different amounts of water are available in different places and at different times of the year. Nevertheless, people living in dry areas still consume water! Indeed, most Americans use water without considering the natural patterns of supply.

Data Box 1

Summary of what happens to water in daily precipitation over 48 contiguous states in U.S. (Average total daily precipitation is 16 trillion liters)

Evaporation from wet surfaces	66%
Stream flow to Atlantic Ocean or Gulf of Mexico	22%
Stream flow to Pacific Ocean	7%
Subsurface flows	2%
Consumed (not immediately returned to the water cycle)	2%
Stream flow to Canada and Mexico	1%

Although there is a lot of water around us, relatively little is available in the form we most want: clean, cheap, and easily accessible fresh water. This is a key point for students to understand. Sometimes considerable engineering feats are undertaken to keep freshwater supplies in pace with our demands. In central Arizona, for example, hundreds of miles of aqueducts were built to carry water from the Colorado River to farms and cities. In some regions, freshwater consumption far outpaces its resupply through precipitation.

Our freshwater supply is like a bank account—water that is withdrawn must be replaced or the account will decline. Without resupply, future withdrawals will become impossible. (Activity Five involves analyzing water consumption data across the country.)

Differences Between Direct and Indirect Water Use

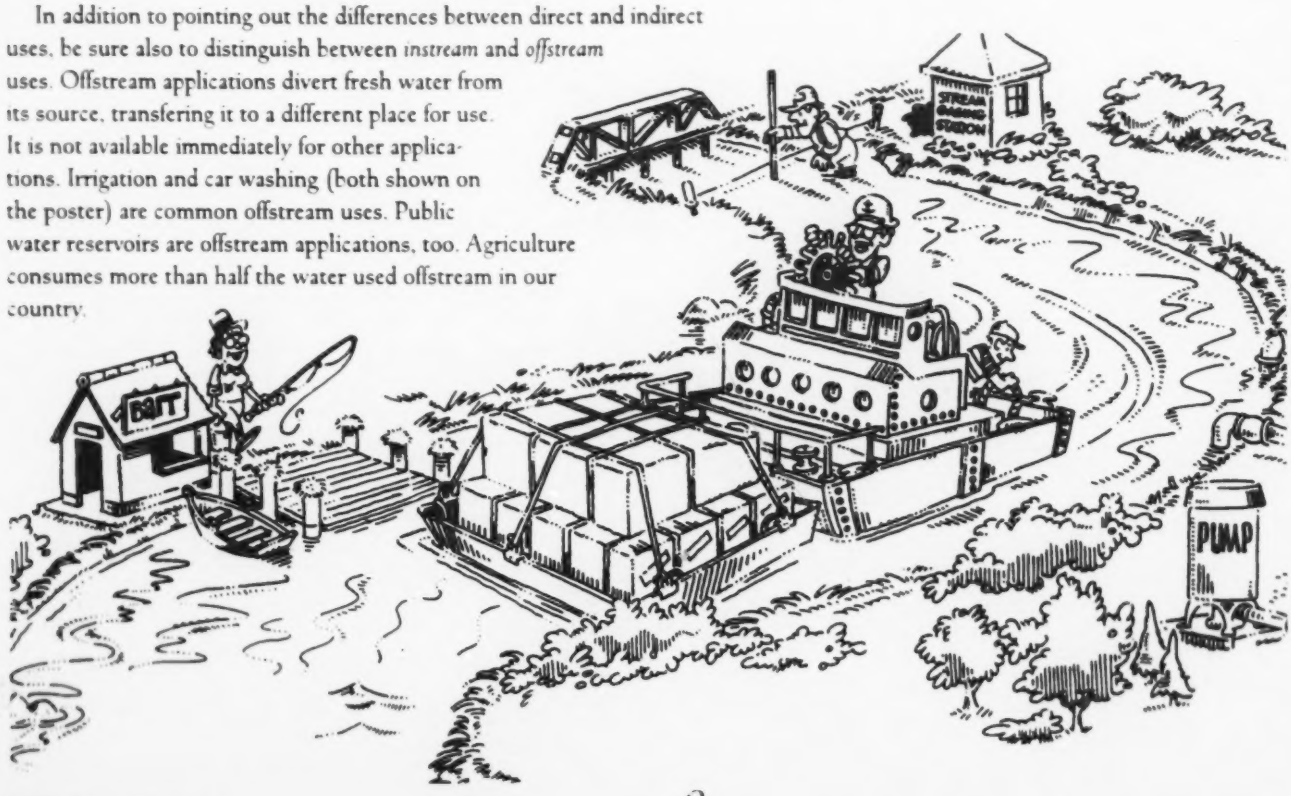
During 1990, roughly 1,300 trillion liters of fresh water were withdrawn from our nation's water sources—that's about 3.6 trillion liters each day. This is roughly 25 percent of what falls annually as precipitation (but remember, of that annual precipitation two-thirds simply evaporates).

On average, in 1990 each American used 5,227 liters of fresh water *every day*. That is a lot of water! We use water directly when we bathe, when we clean dishes, clothes and the car, when we brush our teeth, flush the toilet, and water our lawns. (Activities in this *Teacher's Guide* will raise awareness about the volume of your students' freshwater use.)

But people use much more water *indirectly* than they use directly. If your electric company generates power using hydroelectric generators, you're indirectly "using" water every time you use electricity. Buying and driving a car "uses" water: it was consumed when parts for the car were manufactured and when the petroleum used for gas was refined. Enormous amounts of water are used in agriculture and in manufacturing processes. For instance, to grow enough wheat for one loaf of bread, farmers use 437 liters of fresh water; for one glass of milk, 190 liters are used. A standard-sized hamburger requires 380 liters of fresh water. (Students can trace indirect water use for products in their daily lives—e.g., paper, fruit juice, aluminum cans, or a computer chip. The results will be surprising!)

Differences Between Instream and Offstream Use

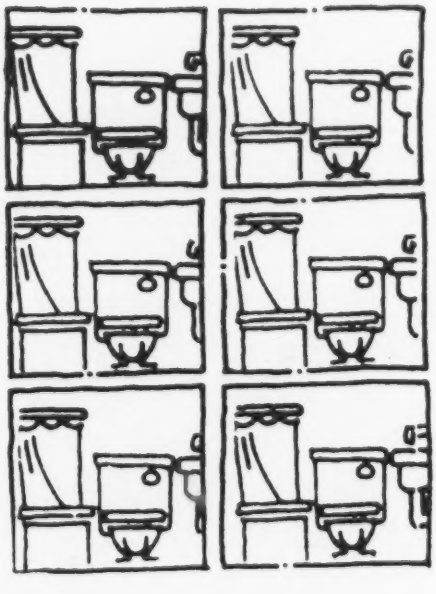
In addition to pointing out the differences between direct and indirect uses, be sure also to distinguish between *instream* and *offstream* uses. Offstream applications divert fresh water from its source, transfering it to a different place for use. It is not available immediately for other applications. Irrigation and car washing (both shown on the poster) are common offstream uses. Public water reservoirs are offstream applications, too. Agriculture consumes more than half the water used offstream in our country.



When water is used instream, it remains in or is immediately returned to its source. It can be used again immediately. Hydroelectric generators in dams use water instream, so do boaters, divers, and people who fish.

Students find this distinction easy at first but have difficulties after some reflection. As a pair of categories, instream *versus* offstream emphasizes the *route* of water use. It is neutral to descriptions of changing water *quality*. To illustrate this point, imagine a motorboat running across a freshwater lake. This is an instream use because the water is kept in its source and can be used again immediately. Don't forget, however, that exhaust from the boat affects the lake's water quality, so does the disturbance caused by the boat's motion. Students should be discouraged from automatically assuming instream uses are friendlier to our environment than offstream uses. (The distinction between instream and offstream uses is developed in Activities Three and Four.)

How Do We Treat Our Wastewater?



Every time we turn on a faucet, fill a bathtub, flush a toilet, or run a washing machine we create wastewater. Everything we send down a drain enters a wastewater system. At least one of these systems operates underneath *your* house, school, and community. What happens to the wastewater we create? "How Do We Treat Our Wastewater?" answers this basic—but often overlooked—question. By studying this poster and completing its related activities students will come to understand the many steps involved in wastewater treatment. They also will be able to identify several types of treatment systems and appreciate the need for water conservation. Remember: improving our environment includes paying attention to how we treat our wastes.

What is Wastewater?

Everything we send down our drains becomes wastewater that treatment facilities must handle. Food dumped in a sink mixes with soapy water from washing machines and bathtubs. Storm drains on the streets sometimes feed into wastewater systems. So might drains at gas stations. Everything that enters the common plumbing will arrive at a wastewater treatment center. The volume of waste entering treatment systems grows every year. Increasing populations, new homes, and new businesses contribute to this rise. So does increased individual consumption. Added to this are products

and services that create more complex wastes, ones requiring more sophisticated pollution-control technologies. Growing populations and increased consumption not only remove resources faster from the environment; they also increase the volume of wastes that are returned to the world around us.

Encourage students to identify as many sources of wastewater as possible. Using the poster, students will spot obvious examples first; more subtle sources are found later. Encourage students to suggest additional sources as well. Furthermore, they should be looking for different treatment systems and for different parts of the treatment process. A range of treatment systems is represented on the poster, from an urban community's large-scale treatment center to smaller scale technologies such as septic tanks, leach fields, lagoons, and sand filters. What kind of treatment technologies are present in your community?

Why Do We Treat Our Wastewater?

Treatment involves removing unwanted materials from wastewater. The goal is to purify water as much as possible (and practical) before it is returned to the environment. In nature, processes occur in wetlands that remove sediments and excess nutrients from used water. This is one reason wetlands conservation is so important (it is discussed in the wetlands section on page 12). But nature's cleaning processes are not enough for the wastes we generate. There are three major reasons why we need to additionally treat the wastewater we generate.

One reason is scale. We generate too much waste too quickly for nature's purification systems to work. The volume of our wastes simply would overwhelm natural cleaning processes.

Another reason involves the kinds of wastes we generate. Sometimes wastewater contains complex chemicals and other pollutants that would not be broken down in nature. It is irresponsible simply to release some kinds of wastewater straight into the environment—such as when it is filled with radioactivity, dangerous concentrations of heavy metals, or disease-causing materials. Think of the consequences if we threw all our trash into the streets or into a local field. Why would we want to do the same with our untreated wastewater?

A third reason is sanitation. A variety of diseases—e.g., cholera and dysentery—thrive where accumulations of wastewater are left untreated. Whenever large numbers of people live in unsanitary conditions, frightening epidemics of these diseases are possible. Students can study conditions in international refugee camps or in so-called "shanty towns" on the fringes of metropolises (e.g., Cairo or Mexico City) to see the connection between wastewater treatment and disease prevention.

When flooding affects cities and towns in the United States, protecting wastewater treatment facilities is a high priority. When these are damaged or flooded, large volumes of untreated wastewater can be released. Public health officials consider any breach of treatment facilities with extreme seriousness because of disease threats. Such was the case during the 1993 flooding in America's central region and during the 1994 flooding throughout Georgia. (The *Reader's Guide to Periodical Literature* is a good source for reports about flooding and public health threats.)

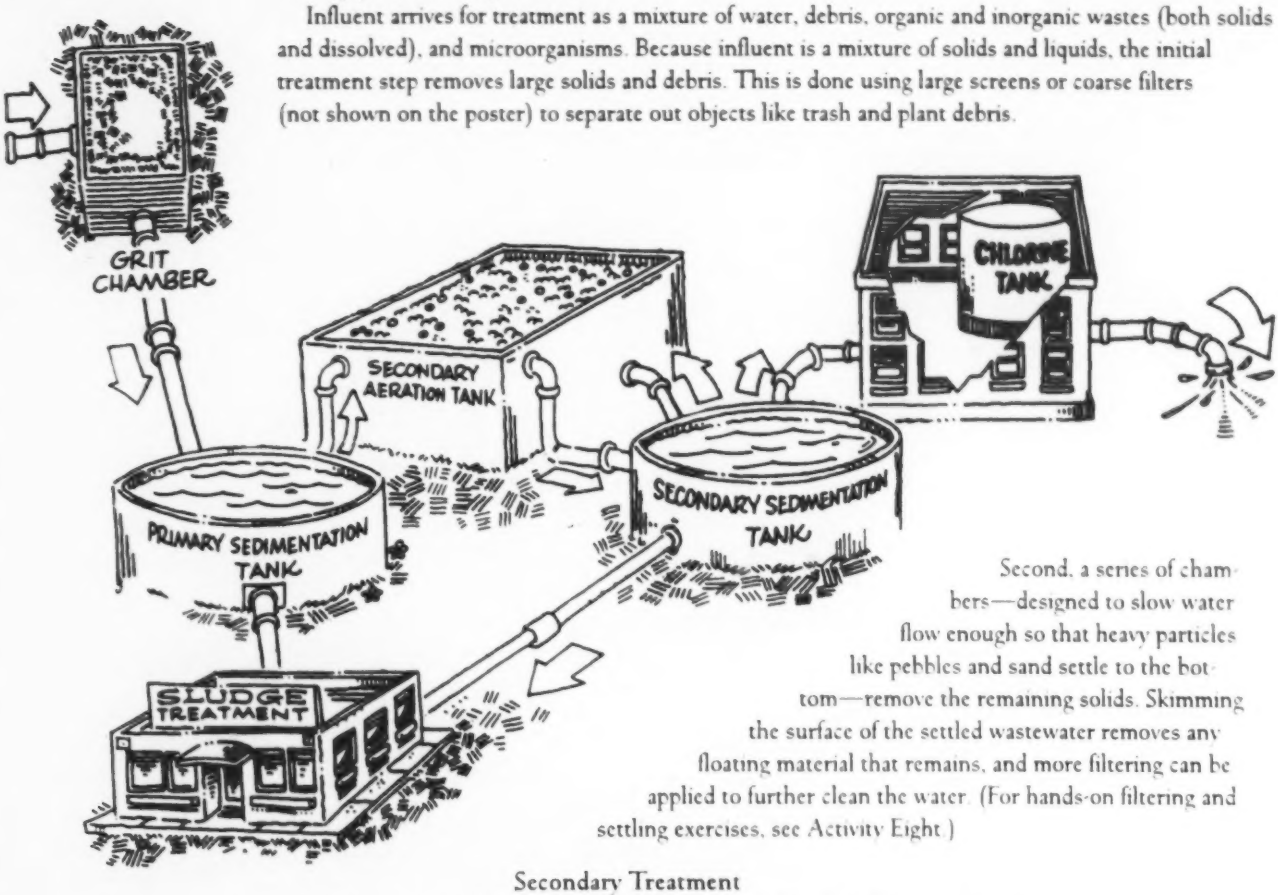
How Does Wastewater Treatment Work?

Wastewater treatment systems vary widely in their scales of operation, arrangement, and technology. At least half a dozen kinds of systems are represented just on the poster! Despite their variety, these systems use the same basic processes for cleaning wastewater: primary treatment removes solids; secondary treatment removes dissolved materials; and additional treatments meet special needs.

Primary Treatment

Wastewater entering a treatment system is called *influent*. Although it may seem obvious, students might overlook the fact that the most abundant component of influent is water itself. Sewage is over 95 percent water. To help follow the process of how influent is treated, locate the *Wastewater Treatment Administration* on the left-hand side of the poster. In that example, primary treatment begins where the sewer pipes enter the grit chamber.

Influent arrives for treatment as a mixture of water, debris, organic and inorganic wastes (both solids and dissolved), and microorganisms. Because influent is a mixture of solids and liquids, the initial treatment step removes large solids and debris. This is done using large screens or coarse filters (not shown on the poster) to separate out objects like trash and plant debris.



Second, a series of chambers—designed to slow water flow enough so that heavy particles like pebbles and sand settle to the bottom—remove the remaining solids. Skimming the surface of the settled wastewater removes any floating material that remains, and more filtering can be applied to further clean the water. (For hands-on filtering and settling exercises, see Activity Eight.)

Secondary Treatment

The goal of secondary treatment is to increase water quality by removing dissolved contaminants and disease-causing microorganisms. Secondary treatment involves several steps and can be done in a variety of ways. The most common secondary treatments use microorganisms. Students may not know that living organisms are used to clean their wastewater!

The most important part of secondary treatment is *aeration*. This is a mechanical process used to add oxygen or air to wastewater while also mixing in recycled organic matter. Aeration promotes the growth of bacteria. Bacteria consume some of the dissolved materials in the wastewater. And while bacteria eat the wastes, other microorganisms—usually protists and algae—eat the bacteria and their byproducts. Growth in the populations of protists and algae is easy to monitor. This cycle—bacteria

eat wastes, protists and algae eat bacteria—can be repeated several times to increase water purity. Overall, this cycle removes up to about 85 percent of dissolved contaminants in the water.

Secondary treatment is performed in a variety of ways. Those shown on the poster include: activated sludge, trickling filters, and lagoons and ponds.

Activated sludge mixes recycled organic material (which supplies the microorganisms) with wastewater. Aeration supplies oxygen for the protists and algae, which in turn convert dissolved wastes into solids that later are separated from the water. Following aeration, the water and microorganisms are moved to a secondary sedimentation tank where accumulated solids settle to the bottom. Although some wastewater is returned to the aeration tank (so that microorganisms are returned to the cleaning process), most is moved to the next cleaning step.

Trickling filters use a bed of rocks or other supporting filters upon which a kind of slime (consisting of protists and fungi) is grown. The organisms in the slime function in the same way as in activated sludge. Wastewater is slowly sprayed over the filters, and as it seeps through, contaminants and pollutants are consumed by the microorganisms.

Sometimes wastewater is emptied into lagoons or ponds after primary treatment. Near the surface, *aerobic* bacteria consume dissolved wastes, pollutants, and dissolved oxygen, releasing carbon dioxide in the process. Protists eat the bacteria. Near the bottom of the pond, *anaerobic* bacteria consume nitrates and phosphates, releasing nitrogen gas and phosphorus. The release of these nutrients, in turn, feed the growth of algae. Through photosynthesis, algae replaces the oxygen that was consumed by other microorganisms in the pond.

Special Treatments and Release

Depending on the kinds of wastes found in influent and on the expected environmental impact of the treated water after it is released, special treatments may be used. For instance, chlorine often is applied as a disinfectant to remove leftover organisms that might cause disease. Chlorine also promotes oxidation, a chemical reaction that aids the conversion of pollutants to harmless substances. In areas where chlorine might be harmful to the surrounding environment, other disinfectants—e.g., ultraviolet light and ozone—are substituted.

After treatment and testing for water purity, wastewater is ready to be discharged into the environment. The released water—called *effluent*—usually is discharged into local surface waters, such as rivers and lakes. Sometimes effluent is used for irrigation or sent to replenish underground water supplies. "How Do We Treat Our Wastewater?" shows a range of uses for effluent.

Sometimes treated wastewater still contains large quantities of dissolved phosphorus and nitrogen. (Phosphorus occurs naturally in human wastes and is an ingredient in detergents. Nitrogen also occurs naturally in human wastes and is a common element in fertilizers.) These two substances serve as nutrients for living organisms. If released as effluent, water with high levels of phosphorus and nitrogen can cause an enormous increase in the number of microorganisms, algae, and plants in the environment. This growth spurt consumes some nitrogen and phosphorus; it also consumes oxygen in the water. As a result, that oxygen is not available for fish and other aquatic life. (This process is called *eutrophication*.) Fish and other creatures also suffer from the release of nitrogen-rich effluent because nitrogen compounds are easily converted in the environment to ammonia, which is toxic.

Nitrogen- and phosphorus-rich effluent can be treated by the addition of certain chemicals that convert these nutrients into biosolids (these can be removed from the water before it is released), or through controlled biological processes where organisms consume these substances under manageable circumstances.

What Happens to the Leftover Organic Waste?

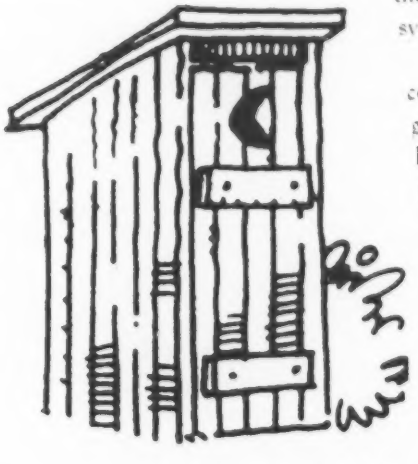
Wastewater treatment involves the separation of wastes and the purification of reusable water. Once cleaned, treated water is released into the environment. Something also must be done with the materials left over. Concerns for public health and the environment have led to strict laws governing the disposal of organic waste—sometimes called sludge or biosolids—from sewage.

If they are relatively clean, biosolids from public water treatment facilities are placed in regular landfills or incinerators. However, because they are nutrient rich, under other circumstances biosolids can be recycled and returned to the environment. Approximately 40 to 50 percent of the 8 to 9 million tons of biosolids produced in the United States each year is recycled for beneficial use. Fertilizers with biosolids are used in a variety of ways, including: landscaping and home gardens, agricultural land used for commercial crops, forested areas, parks, and recreation areas.

Although carefully treated before their use as fertilizer, biosolids are not used on crops intended for direct human consumption. This safety precaution is due in part to concerns about the spread of disease (although this risk is extremely low). More importantly, biosolids can contain large concentrations of heavy metals (such as lead) and other materials not safe for human consumption. Close monitoring of the composition of biosolids helps protect consumers from their unsafe use.

What Kinds of Water Treatment Systems are Used?

Wastewater treatment systems exist on a variety of scales. An outhouse is a wastewater treatment center of sorts. On the opposite end of the scale are huge facilities designed for the wastewater of whole communities. These use a maze of sewer pipes that feed into a central treatment facility. Wastewater flows through the sewers by gravity, assisted in some spots by pumping stations. Such large-scale facilities, like the *Wastewater Treatment Administration* on the poster and those discussed above are examples of *off-site* wastewater treatment systems.



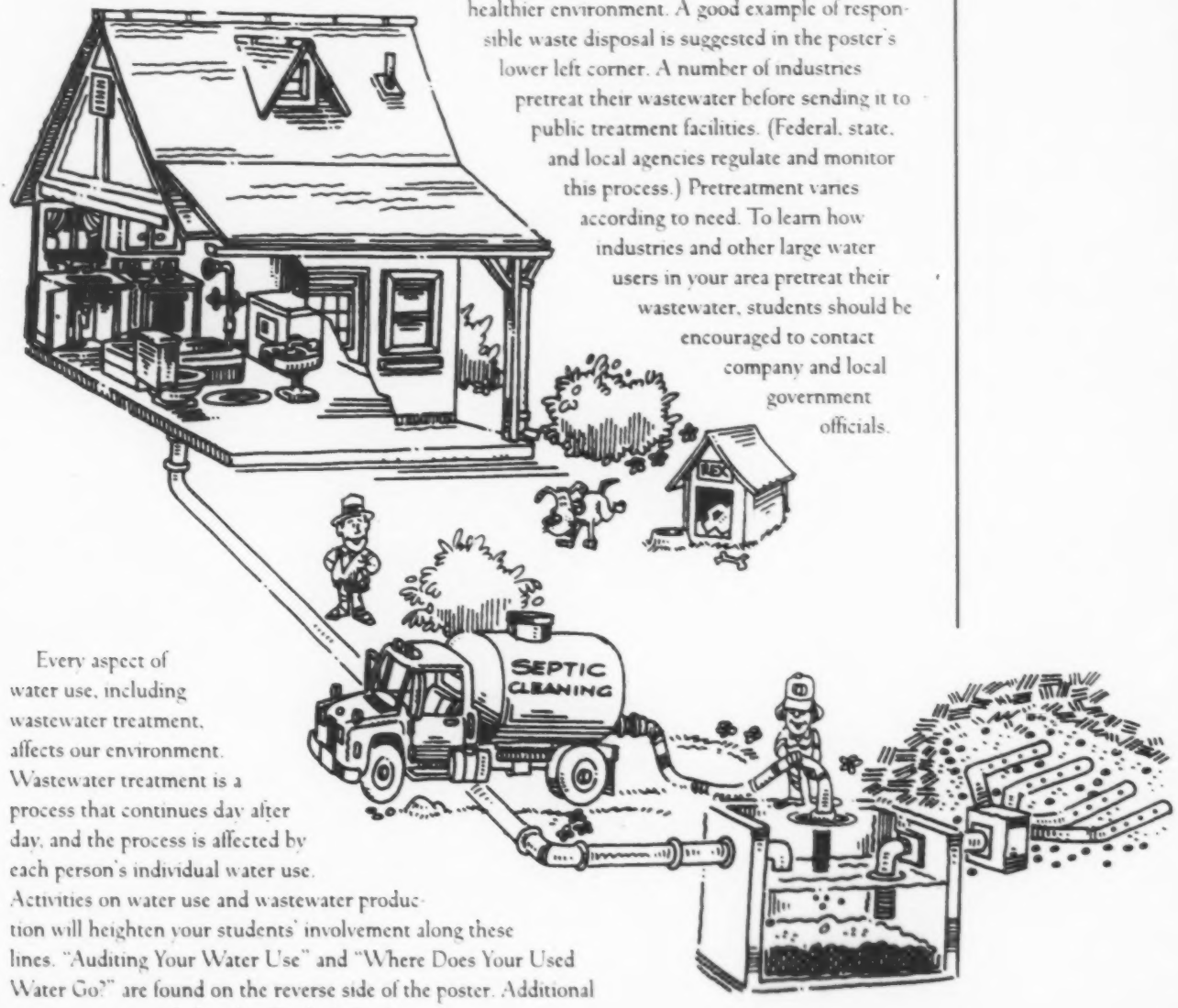
Septic tanks—illustrated on the right-hand section of the poster—are common *on-site* treatment techniques. (Other kinds of on-site technologies are shown in the poster as well.) Septic tank systems use a large buried tank that can hold several days worth of wastewater. In the tank, primary and secondary treatments are combined. Natural processes are allowed to work: solids settle, grease lumps together, and organic matter decomposes both by natural chemical reactions and by the activity of microorganisms. Sometimes this secondary treatment is augmented with the addition of other organisms, enzymes, or chemicals. Effluent slowly flows from the main chamber into leach fields, where it percolates into the soil.

Septic tanks are common in areas where large-scale wastewater treatment facilities either have yet to be built or are not cost-effective. Although usually reliable, septic tanks must be properly installed and maintained to operate efficiently. They also must be periodically drained so that accumulated solids can be removed. Because of their size and pace of operation, septic tanks have specific capacities. Users of septic tanks are extremely conscious of their tank's capacity and about what wastes are put into them.

The *Lodge Trailer Park* in the upper middle portion of the poster is an example of a medium-scale technology. This system is common in small but densely-populated communities and private establishments. Campgrounds and mobile home parks often use such techniques. After passing through a septic system, wastewater is piped into a lagoon, where biological activity and natural chemical reactions combine to clean the water.

We are Responsible for Our Wastewater!

Regardless of the system used, everything we send down our drains becomes part of the wastewater that must be treated. Responsible disposal practices must be taught and followed. Pouring paint or oil into a drain means that a wastewater treatment facility must remove it, costing extra money and complicating the process. And if a facility is not able to remove such wastes, they enter and pollute our environment. Teach students to think about the way they dispose of wastes and to realize that responsible waste handling means contributing to a healthier environment. A good example of responsible waste disposal is suggested in the poster's lower left corner. A number of industries pretreat their wastewater before sending it to public treatment facilities. (Federal, state, and local agencies regulate and monitor this process.) Pretreatment varies according to need. To learn how industries and other large water users in your area pretreat their wastewater, students should be encouraged to contact company and local government officials.



Every aspect of water use, including wastewater treatment, affects our environment. Wastewater treatment is a process that continues day after day, and the process is affected by each person's individual water use. Activities on water use and wastewater production will heighten your students' involvement along these lines. "Auditing Your Water Use" and "Where Does Your Used Water Go?" are found on the reverse side of the poster. Additional activities are provided in this *Teacher's Guide*.

Wetlands: Water, Wildlife, Plants & People!

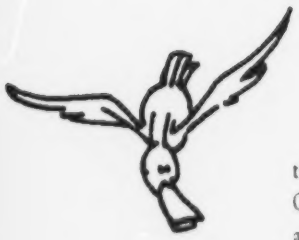
Using "Wetlands: Water, Wildlife, Plants & People!" will help students understand what wetlands are, that they are not all the same, and that wetlands perform important functions in ecosystems. Students also will learn how we use and benefit from wetlands.

Why are Wetlands So Important?

For a long time, wetlands were thought of as *wastelands*: muck-filled, smelly places infested with mosquitoes, biting flies, poisonous snakes, and diseases. Wetlands were considered to have little economic value. They were drained, ditched, and filled. They were turned into farm land in agricultural areas, and into houses, offices, industrial facilities, or sanitary landfills in built up areas.

But during the past few decades, this attitude has changed. Today we understand the important role wetlands have in ecosystems and in the natural recycling of materials. We use wetlands more than we thought we did! Understanding the need for their conservation will come easy to students once they recognize what wetlands do in nature and how those functions affect our daily lives.

Wetlands are valuable on several levels. For one, they are vital—sometimes the only!—habitats for many plants and animals. In fact, the majority of threatened and endangered animal species in our country depend on wetlands for their survival. For another, wetlands are natural water filters, improving water quality by filtering sediments and nutrients. The filtered water soaks into the aquifer or flows into nearby streams and rivers. For a third, wetlands reduce flood and storm damage by dispersing flood waters. They minimize erosion, generate a wealth of natural products, and support tourism and the hunting and fishing industries. Students will find these wetlands uses displayed on the poster. They also might be able to add more.

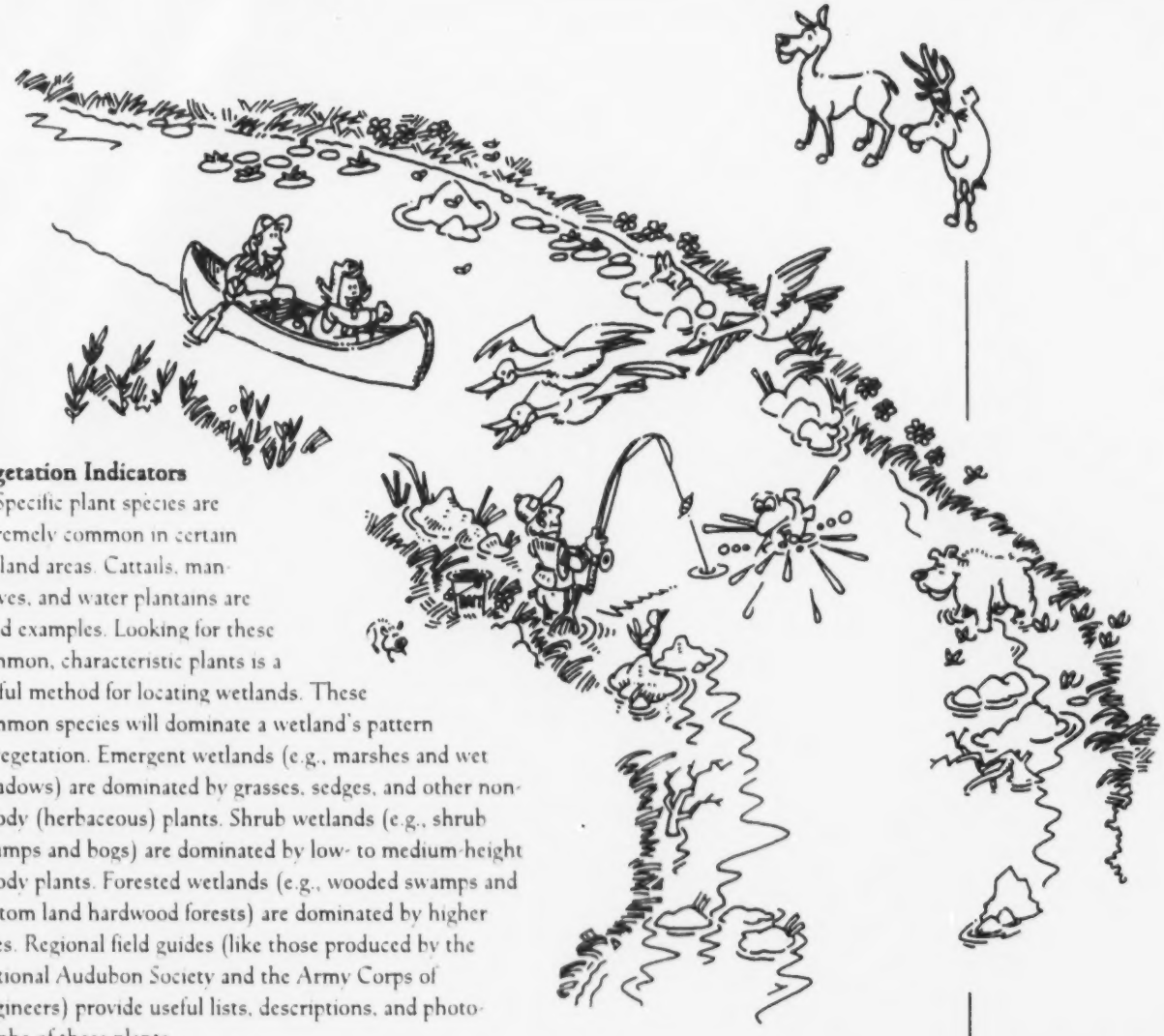


What Makes Wet Land a Wetland?

When asked to describe wetlands, most people think of marshes and swamps. This is a good start, but there is far more to wetlands. As a working concept, think of wetlands as transitional areas between land and deep water—where the soil is saturated for long periods of time. Or, think of wetlands as areas covered by shallow water for at least part of the year. Besides swamps and marshes, wetlands occur in other locations, even in places that don't seem to be wet. Forested wetlands fall into this latter category. While their soils may not be saturated during the summer, forested wetlands become waterlogged in winter and spring. Under normal circumstances, wetlands support a variety of plants and animals specially adapted for living in saturated soil.

Wetlands can be classified by their location (as they are on the poster). *Inland* wetlands include freshwater marshes, swamps, and bogs that are relatively unaffected by ocean-driven tides. Inland wetlands are found on flood plains along rivers and streams, along the margins of lakes and ponds, and in isolated depressions elsewhere. *Coastal* wetlands are tidal marshes and mud flats that periodically flood with salt or brackish water. These are found along tidal rivers and saltwater bays. Much of the nation's coasts form wetland areas, but your students will be surprised to learn that these areas comprise only about 5 percent of all wetlands in our country! Wetlands occur in every state of our nation, although they vary in size, shape, and type. Your state's department of natural resources or department of agriculture can help you find nearby wetlands.

When scientists and geographers classify wetlands, they emphasize three technical indicators: vegetation, soil type, and hydrology. Unless the area being studied was altered by human use, all three indicators must be present for an area to be counted as wetlands.



Vegetation Indicators

Specific plant species are extremely common in certain wetland areas. Cattails, mangroves, and water plantains are good examples. Looking for these common, characteristic plants is a useful method for locating wetlands. These common species will dominate a wetland's pattern of vegetation. Emergent wetlands (e.g., marshes and wet meadows) are dominated by grasses, sedges, and other nonwoody (herbaceous) plants. Shrub wetlands (e.g., shrub swamps and bogs) are dominated by low- to medium-height woody plants. Forested wetlands (e.g., wooded swamps and bottom land hardwood forests) are dominated by higher trees. Regional field guides (like those produced by the National Audubon Society and the Army Corps of Engineers) provide useful lists, descriptions, and photographs of these plants.

Another way plants indicate wetlands is by their structure. Plants adapt to wet soil conditions in characteristic ways. Because wetland soils commonly are water-soaked, trees in wetland areas usually have shallow root systems, swollen trunks, or roots found growing above the soil surface. Knowing to look for these kinds of adaptations, students can locate wetlands easily (and without having to memorize plant names).

Soil Indicators

Wetland soils (also called *hydric*—meaning an abundance of water—soils) possess distinctive features because of their prolonged saturation (Data Box 2). First, the soil is anaerobic—i.e., it lacks oxygen—because most or all of the pore spaces are filled with water and there is little or no room for trapping oxygen. Second, certain kinds of chemical reactions occur in hydric soils because of the

Data Box 2

Soil Indicators

Wetland soils frequently display some of the following features:

- soil consisting of peat or organic material
- soil that sticks together or oozes out of your fingers when squeezed
- soil that smells like rotten eggs or sulfur (caused by hydrogen sulfide, a product of anaerobic conditions)
- light gray soil that contains splotches of red, orange, or yellow (This "mottling" is caused by seasonal fluctuations in the water table, where the soil is alternately wetted and drained, and by natural bacterial action that causes the metals in the soil to rust.)

Hydrological Indicators

To identify areas where periodic flooding occurs, hydrologists look for the following indicators:

- standing or flowing water for seven or more consecutive days during the growing season
- water-logged soil (This is determined by digging down 30 centimeters, then examining the hole for standing water.)
- water marks on trees or other standing objects
- drift lines or small piles of debris oriented in the direction of water movement
- thin layers of sediments deposited on leaves or other objects

saturated and anaerobic conditions. As a result, the physical properties of wetland soils are different from soils in other areas. Third, because wetland soils lack oxygen, only certain microorganisms—those capable of anaerobic respiration—are found in them.

Your state agricultural extension service, state soil survey, or your local office of the Army Corps of Engineers can provide you with information about specific soils in your area. Students can investigate many topics related to wetland soils—in the U.S. there are about 2,000 soil types that occur in wetlands!

Data Box 3

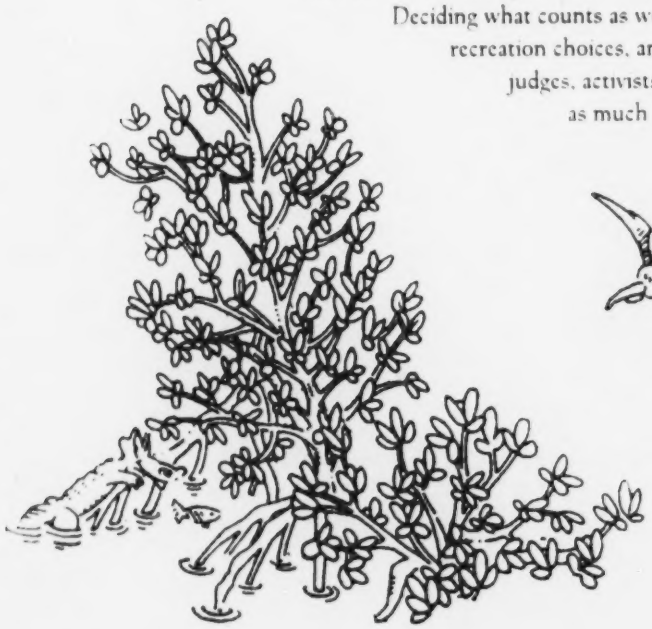
Hydrology Indicators

The mere presence of water is not enough to indicate a wetland area. Instead, hydrologists (geologists who study water patterns and distributions in soil and rock formations) look for signs that the soil has been saturated long enough to influence the plant and soil types in the area (Data Box 3). Of course, the most easily recognized wetlands are found near bodies of water. But remember, wetlands need not always be wet!

Why is Wetlands Classification Important?

Scientists and geographers identify a variety of wetland types. Each type has particular features and resources. Their conservation requires different approaches. But scientists and geographers are not the only people interested in wetland classification.

Since the need to conserve wetlands was recognized, a range of federal, state, and local regulations has been put into effect restricting how wetlands can be used. If a lakeside plot is designated as a wetland area, then building on that plot might be stopped or tailored to that special circumstance. Draining marshes to expand farms, roads, or houses also can be prohibited to preserve wetland areas. In the reverse, flooding otherwise dry areas to create recreational lakes might be encouraged. Deciding what counts as wetlands is crucial for land use decisions, real estate prices, recreation choices, and a wide range of other aspects in our daily lives. Lawyers, judges, activists, and politicians are involved in wetland classification just as much as scientists and geographers are.



In 1974, the U.S. Fish and Wildlife Service launched the National Wetlands Inventory (NWI) to collect and distribute information about the nation's wetlands. In response to growing concern about wetlands loss, the U.S. Congress in 1986 required the Fish and Wildlife Service to update that inventory every 10 years. For 1990, NWI reported the total acreage of wetlands to be approximately 88 million acres. This total compared to 106 million acres in the mid 1970s.

Why Teach About Wetlands?

Comparing the two NWI surveys demonstrates why knowing how wetlands are classified is important. In the time between the two surveys, classifications changed. Earlier surveys sought lands that could be drained for agriculture. Later surveys were more concerned with preserving wildlife habitat. The difference makes *directly* comparing the two reports difficult. Learning how to dissect studies like these—to find out what the numbers are *really* telling us—is a central element of science literacy. By *any* measuring technique, our country has been losing wetlands at an astonishing rate: no state has more than 50 percent of its original wetlands, and some states have lost nearly *all* their wetlands! By 1981, for example, Iowa had lost 99 percent of its natural wetlands; by 1982, Nebraska had lost 91 percent. (For information about your state, consult the *Atlas of United States Environmental Issues*, listed in the Resources List.) Understanding the more subtle aspects of this loss and deciding what to do about it require a detailed understanding of the situation. This is one reason for including wetlands education in your curriculum.

In addition, students need to understand that wetland areas are valuable natural resources. Wetland habitats provide the necessities of life not only for many endangered and threatened species, but also for us. These necessities include: abundant food sources, a system for natural water purification, and space to live and grow. Remember, too, that simply enjoying the beauty and sounds of nature is valuable in itself. Often when outdoors enjoying nature, we are in wetland areas. Many family vacations involve traveling to or through wetlands. This important part of wetlands appreciation should not be overlooked! It is a place where students can draw directly from their own experiences.

Water quality and supply are among the most important issues facing Americans moving into the twenty-first century. Students should know how wetlands contribute to improving our nation's water quality and supply. Between water filtration, flood control, and freshwater storage, wetlands have a central role in our water use system.

Every state in our nation has wetlands that students can study in detail. Some states—Alaska, Florida and Louisiana—make interesting case studies because they possess a high percentage of wetland area. On the back of the wetlands poster you will find a variety of activities, including "Wetlands Habitats" (about classifying wetlands), "Wise Wetlands Ways" (about human uses of wetlands), a wetlands model, and a wetlands visit simulation. Other activities are provided in this *Teacher's Guide*.

Activities for Students

This section presents activities that use and extend the water resources posters discussed above. These are hands-on, interactive activities, with special attention paid to cooperative learning, interdisciplinary studies, and science literacy. Activities are keyed to particular posters, and several sequences—where one activity builds on the previous one—are included for larger lesson blocks. Additional curriculum materials and reference guides are identified in the Resources List on pages 30-31.

Two copies of each poster—one for middle level, another for primary level—accompany this *Teacher's Guide*. Your first preparation step should be to make several high-quality photocopies and transparencies of the panels on both sides of each poster, storing masters for future use. Once the panels have been copied, cut one of the posters for each subject into sections. Students will use these sections in many of the activities below. To add durability, laminate the full poster and the poster sections. (Because poster sections will be used by students and because the material on the reverse side—the side with text—may distract them from their assignments, you should consider covering the reverse side with colored paper or card stock prior to lamination.) Additional copies of each poster can be obtained through the U.S. Geological Survey.

Best results are obtained when posters are hung where students can closely examine them. If you have no room on walls or bulletin boards, try alternatives such as easels. The poster you display will change depending on your choice of lessons and activities; however, these three posters are designed to be interconnected. Appreciating the interconnections of water use is a central objective of this project. As your lessons progress, attach the first poster studied to the second, which can be attached to the third, as each is introduced.

Activity One
Keeping a Water Journal

In this first activity, students construct a Water Journal for use in water resources activities. After creating their journals, students make a preliminary survey of their own water use during the next 24 hours. This preliminary listing will be extended and reexamined in subsequent activities.

Journal keeping is a useful pedagogical technique. Students who keep journals have the records of classroom activities and assignments collected in a single place. They have a storage device for notes and information. They have a forum for creative work and reflection and a physical record to show how their knowledge has grown. Teachers who assign journals have a mechanism for building on previous lessons: written records from earlier activities can be referred to and extended. Journals also provide teachers with a convenient record for assessment. Student progress is easy to track when assignments are compiled in a central location.

Making a journal can be as easy as stapling together some blank sheets of loose-leaf paper. To increase involvement, provide room for creativity. The journal could have covers of construction paper or card stock. On the cover, students might draw activities related to a suggested water use, create a collage of images taken from magazines, or paint a water-related scene. Set aside the first page of each journal for a table of contents. Another page might be used as a record keeper, where students can keep track of homework assignments, project collaborators, and directions from the teacher. Pages should be numbered to allow reference in the table of contents.

Start water resources lessons on the day the *Water Journals* are created. Begin a 24-hour period where your students record their water use. Ask them to write down every time they use water over the next day, listing the approximate time they used it and the activity. Allow entries to be general in this initial project, such as "7:15 a.m.: took 5-minute hot shower," or "12:15 p.m.: quick drink at the water fountain." At the end of the 24-hour period, ask your students to summarize their

water use and compare their records with others in the class. Who uses the least water? What is the most common use? How does water use vary? Students will use this list extensively in activities below.

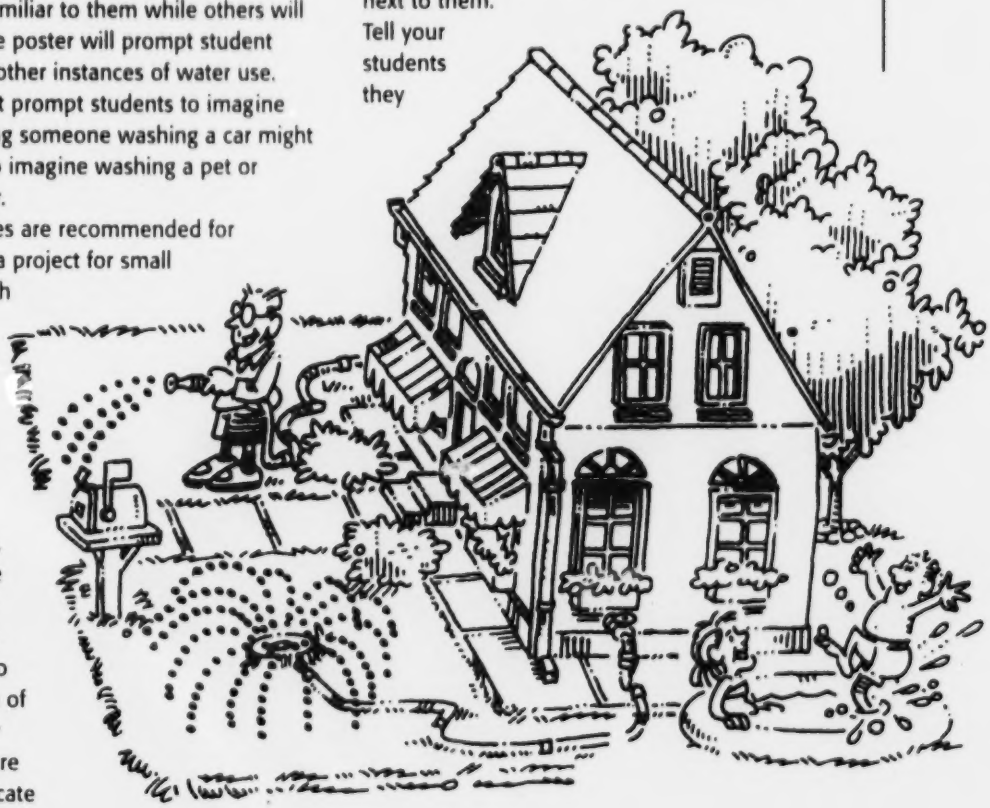
Activity Two
Water Gets Used, & Used, & Used

This activity builds a better understanding of water consumption by introducing several categories of water use and by asking students to closely examine water activities in the poster, "Water: The Resource That Gets Used & Used & Used for Everything." Students will locate familiar examples and categories of water use. They also will explore water uses they otherwise may not have thought of.

The poster, "Water: The Resource That Gets Used & Used & Used for Everything," shows a range of water uses. Close interaction with the poster gives students two opportunities to learn more about water use. First, they will find many examples of water use on the poster itself. Some will be familiar to them while others will not. Second, the poster will prompt student thinking about other instances of water use. Sprinklers might prompt students to imagine fountains; seeing someone washing a car might prompt them to imagine washing a pet or taking a shower.

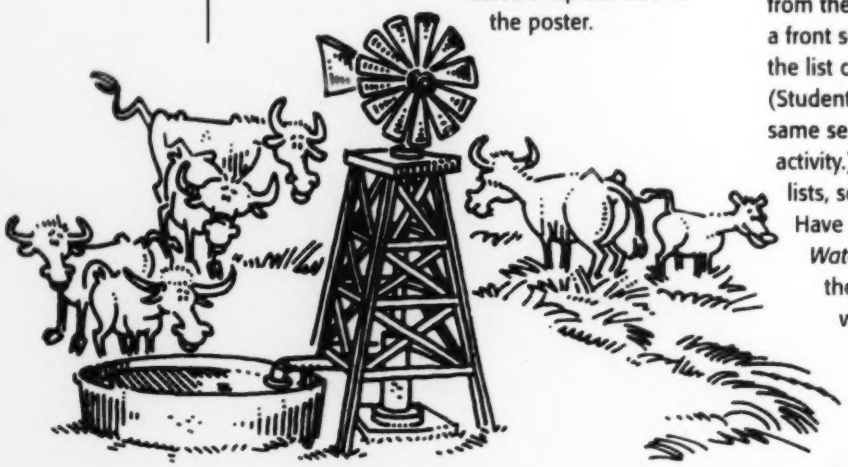
Two strategies are recommended for this activity. As a project for small groups, use both the whole poster and the poster sections created earlier. Display the poster for the class to see. Then, divide the class into eight working groups and distribute to each group one of the eight poster sections. (Be sure students can locate their section on the whole poster.) Ask them to work together and make a list of all the water uses they can for their section. These lists should be copied into each student's *Water Journal*, then collected and saved for a later activity. Students also can report their findings to the entire class. Have overhead transparencies of each poster section ready and project the section on a screen for the class to see while students point out uses found in that section. Recording these uses in everyone's *Water Journals* will be useful for Activity Three below. It also will keep attentiveness high. After their reports are completed, ask the class if the groups missed some water uses.

To do this activity with the entire class, display the poster in a location where your students can easily view it. Start a list on the chalkboard, or on a large piece of paper, called "Water Uses" that students will contribute to. Explain to your students that everyone will be expected to locate at least two water uses and contribute them to the list. Begin the list by identifying two water uses yourself. Place them on the "Water Uses" list and write your name next to them. Tell your students they



should do the same during their free time in the next day or two. Also tell them that duplicating uses on the list will not count. You might choose to highlight some of the more creative identifications. Keep a copy of this list for use in Activity Three below. Be sure students copy the list into their *Water Journals*.

Extensions: Students can select a particular water use from the poster and write a short story describing that water use: perhaps a story about the owners of the tugboat or the people watering their lawns. Ask your students to reexamine their 24-hour water use record to see if some things were missed. Do their records represent use for a typical day? Does their water use vary over the week (e.g., if they bathe on certain days and not on others)? Does it vary from weekdays to weekends? How does their water use vary over the year—do they use more in the summer or winter? Are there obvious ways to save water? In addition, students may know family members, parents of friends, or neighbors who make their living in careers represented on the poster.



Activity Three
Instream and Offstream Use

This activity introduces the distinction between "instream" and "offstream" water uses by studying "Water: The Resource That Gets Used & Used & Used for Everything." Students will work in small groups, examining poster sections to categorize uses based on this distinction.

Drawing the distinction between instream and offstream activities helps separate and organize different kinds of water use. Instream use does not require the removal of water from its source (e.g., a hydroelectric generator in a dam). Offstream use diverts water from its source and transfers it to a different place (e.g., irrigation or swimming pools).

Divide your class into small working groups and describe the different concepts of instream *versus* offstream use and direct *versus* indirect use. As you discuss these differences, you may want to show overhead transparencies of the "Instream Use" and "Offstream Use" panels from the poster's reverse side. Give each group a front section from the poster and a copy of the list compiled for that section in Activity Two. (Students learn best if they do not have the same section they examined in the previous activity.) Ask the groups to work through their lists, separating instream from offstream uses. Have students record these findings in their *Water Journals* as well as report them to the class. Ask students to investigate which uses *consume* the most water and which uses *need* the most water—the distinction is an important one.

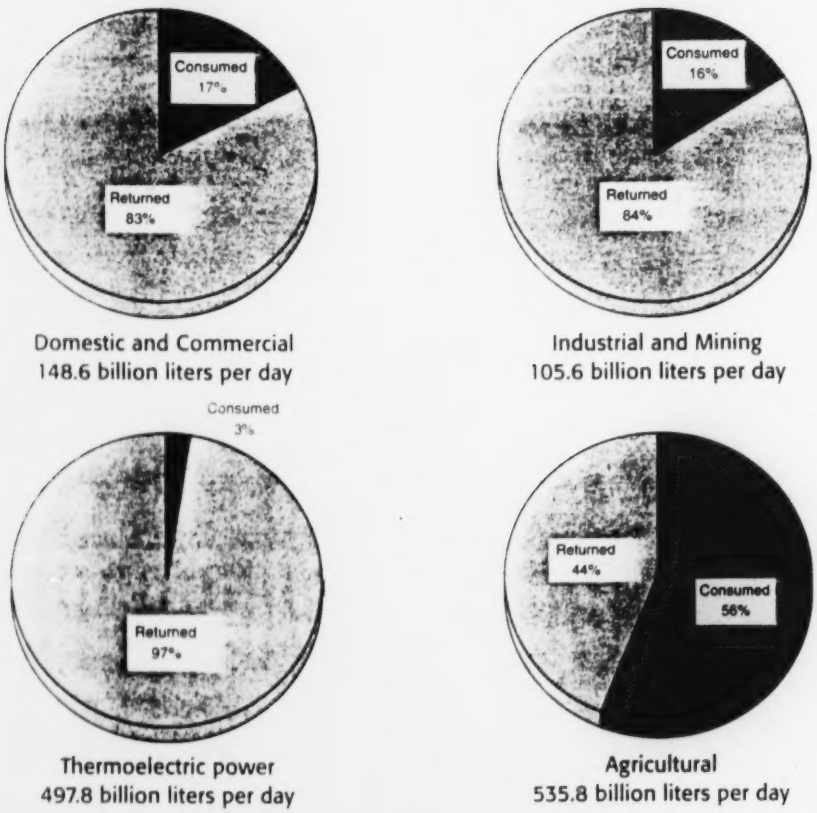
Students may wonder about the sharpness of the distinction between "instream" and "offstream" use. Some water uses are difficult to categorize this way. As they explore the poster, your students

Data Box 4

How Water Was Used During 1990

	% Consumed	% Returned	B liters/day
Domestic and Commercial	17.3	82.7	148.58
Industrial and Mining	16.1	83.9	105.64
Thermoelectric power	2.7	97.3	497.80
Agricultural	56.2	43.8	535.80

Source: *Estimated Use of Water in the United States, 1990* U.S. Geological Survey Circular 1081, page 21



Volumes are for the entire United States of America.
Source: *Estimated Use of Water in the United States,*
U.S. Geological Survey Circular 1081, page 21

Figure 2
How Water Was Used During 1990

probably will find water uses that can be counted both as offstream and instream (e.g., the catfish farm in the middle portion of the poster).

Extensions: Ask students to investigate one example of both instream and offstream use. Ask your students to create a *revised* water report from Activity One. Remind them about uses important to their lives that might be hidden "behind the scenes," such as hydroelectric power generation or irrigation of the crops that go into their foods. Ask them to mark whether the uses they reported are direct or indirect. Most likely, they will have many more direct than indirect uses listed.

Students also can investigate how conservation efforts are interconnected with ongoing water use. Ask them to look for places on the poster where they would focus conservation efforts. If they were governor of the imaginary state shown on the poster, where would they look if asked to improve water quality. What would they do to increase freshwater supplies?

Activity Four
Water Use Comparisons: 1985 versus 1990

On the reverse side of each version of "Water: The Resource That Gets Used & Used & Used for Everything" is a panel of pie charts, "How Water Was Used During 1985." In this activity, students examine this data and compare it to similar data for 1990. Students consider different categories of water use and learn the distinction between "consumed" and "returned" water. In the process, they build graph-reading skills.

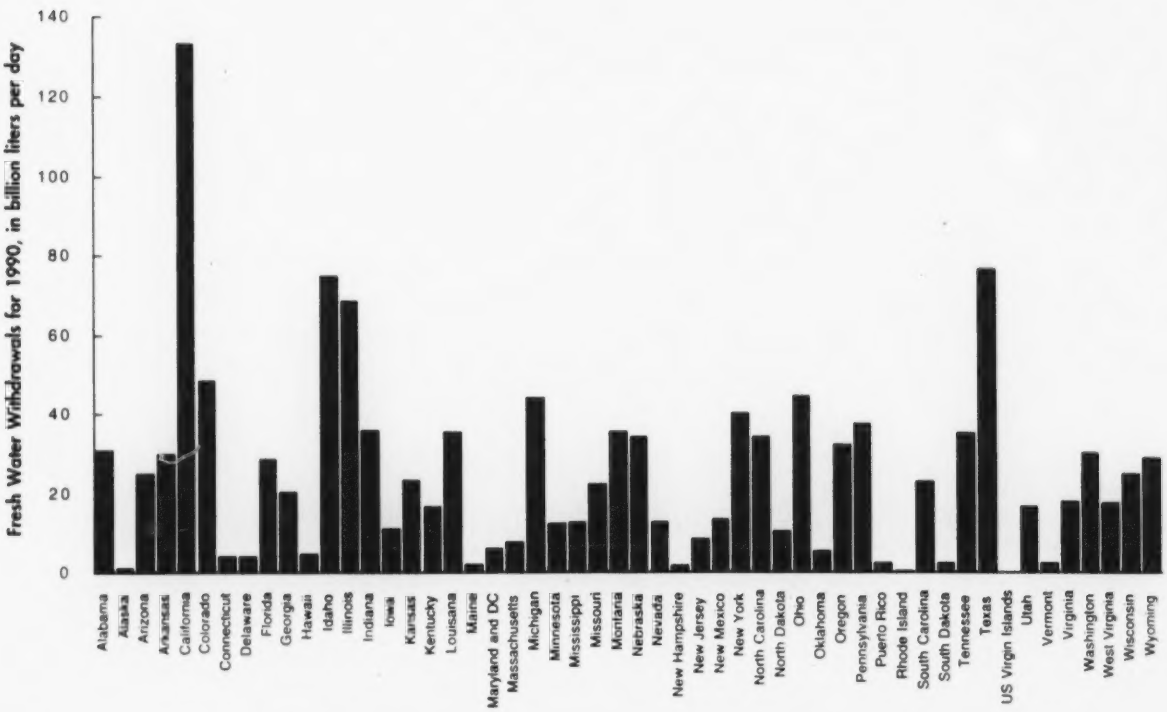


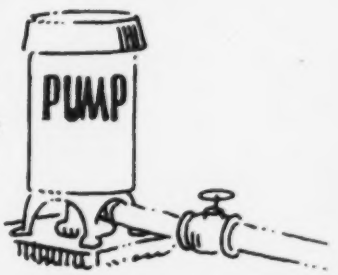
Figure 3
Total Fresh Water Withdrawals in 1990, by state. (Statistics drawn from Data Box 5)

Begin this activity by dividing your class into either four or eight discussion groups. Distribute one or two poster sections to each group and ask them to find examples of each of the following kinds of water use: domestic, commercial, industrial, mining, thermoelectric, and agriculture. These examples should be listed in each student's *Water Journal*. (Note: not all categories are represented on every panel. However, encourage students to be creative in their search.) List each group's findings on the chalkboard so they can be referred to later.

When students have completed their search, ask them whether or not the water in each case is *consumed* or immediately *returned* to the water supply. Estimate how much water is consumed and returned in each case. On the basis of these estimates, rank these six kinds of water use in terms of which consumes the most water.

Show your class a transparency of the pie charts provided in the "How Water Was Used During 1985" panel. How do the estimates your students made compare with this data? Discuss the different kinds of uses, making certain that students understand the major sources for each category. Why do different kinds of uses consume more water than others? Have students reproduce these pie charts in their *Water Journals*. (Be sure this is done in a way that allows them to add copies of the pie charts for 1990 later in the activity.)

Once students are comfortable reading these pie charts, show them the pie charts for water use in 1990 (Figure 2; for only totals, use Data Box 4), and ask them to compare the two data sets. Have students reproduce the 1990 pie charts alongside those for 1985 in their *Water Journals*. How has water use changed? How might they explain that change (or lack of change)? Comparing the pie charts provides the opportunity to investigate changes in the *percent* of water consumed relative to the percent of water returned. To see if one type of activity involved *more* water in 1990 than in 1985, compare the absolute volume numbers underneath each pie chart. Do these values increase or decrease over the 5-year interval? How might your students explain these changes and what are the implications for freshwater supplies?



Extensions: Find water use

Data Box 5

Fresh Water Withdrawals, 1990
(Withdrawals might not add to totals because of independent rounding)
Withdrawals in million liters per day
Source: *Estimated Use of Water in the United States in 1990*, U.S. Geological Survey Circular 1081, pages 13, 15, and 17.

	Total withdrawals	National rank	Surface water withdrawals	Ground water withdrawals
Alabama	30,704	17	29,184	1,497
Alaska	1,079	50	840	243
Arizona	24,966	22	14,554	10,412
Arkansas	29,792	19	11,894	17,898
California	133,380	1	77,900	55,480
Colorado	48,260	5	37,658	10,526
Connecticut	4,066	43	3,428	627
Delaware	3,914	44	3,568	338
Florida	28,614	21	10,906	17,708
Georgia	20,102	27	16,302	3,785
Hawaii	4,522	42	2,280	2,238
Idaho	74,860	3	45,980	28,842
Illinois	68,400	4	64,980	3,496
Indiana	35,834	10	33,478	2,360
Iowa	10,868	36	9,006	1,881
Kansas	23,104	24	6,536	16,568
Kentucky	16,416	31	15,466	939
Louisana	35,302	12	30,210	5,092
Maine	2,022	48	1,695	323
Maryland and DC	5,928	40	4,978	946
Massachusetts	7,714	39	6,422	1,284
Michigan	44,080	7	41,420	2,671
Minnesota	12,426	35	9,424	3,029
Mississippi	12,616	34	2,462	10,146
Missouri	22,306	26	19,570	2,763
Montana	35,340	11	34,580	779
Nebraska	33,972	14	15,770	18,202
Nevada	12,692	33	8,664	4,028
New Hampshire	1,596	49	1,353	243
New Jersey	8,436	38	6,270	2,151
New Mexico	13,224	32	6,536	6,688
New York	39,900	8	36,670	3,188
North Carolina	33,972	15	32,300	1,653
North Dakota	10,184	37	9,652	536
Ohio	44,460	6	41,040	3,435
Oklahoma	5,396	41	2,888	2,516
Oregon	32,034	16	29,108	2,915
Pennsylvania	37,354	9	33,478	3,876
Puerto Rico	2,189	47	1,592	597
Rhode Island	505	51	410	95
South Carolina	22,800	25	21,736	1,072
South Dakota	2,250	46	1,296	954
Tennessee	34,922	13	33,022	1,911
Texas	76,380	2	48,260	28,044
US Virgin Islands	35	52	28	7
Utah	16,644	30	12,958	3,663
Vermont	2,402	45	2,231	171
Virginia	17,898	28	16,226	1,683
Washington	30,058	18	24,548	5,510
West Virginia	17,404	29	14,668	2,766
Wisconsin	24,738	23	22,154	2,588
Wyoming	28,804	20	27,360	1,459
Total	**1,286,864**		**984,939**	**301,822**

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data for your state or municipality. Your state's department of natural resources or your municipal water commission can supply water use information for your region. The U.S. Geological Survey compiles state-level data in the *Estimated Use of Water in the United States* series, published every five years, and in other occasional reports. See the Resources List below for publication and contact information.

Activity Five
Freshwater Withdrawals

This activity builds graph-making and graph-reading skills by presenting data on freshwater withdrawals in all states and asking them to analyze and present that data in meaningful ways. Students also compare freshwater withdrawal data for 1985 and 1990.

On the reverse side of the middle level version of "Water: The Resource That Gets Used & Used & Used for Everything" is a bar graph, "Freshwater Withdrawals," together with a table titled "Summary by State of Freshwater Withdrawals, 1985." Provide your students with copies of each panel. Be sure students understand each of the axes on the graph and each of the columns on the table. You can quickly check their comprehension by asking questions about specific values on the table (e.g., what was Minnesota's ranking for 1985?).

Science involves analyzing data. Using the bar graph and the table, students should be asked to analyze this data. Ask questions along several different lines of inquiry:

- How many states withdraw less than 25 billion liters each day? How many withdraw over 50 billion liters each day? Why are some states withdrawing so much more water than others?

- What *regions* withdraw the most water? Do western or central states withdraw more than eastern states? Compare this with what students have learned elsewhere about population, climate, and agriculture in these regions.
- Do larger states always withdraw more water than smaller states? Compare the size of the states that are ranked first through fifth with the size of states ranked forty-fifth through fiftieth (or for other rank intervals)?

The table of withdrawal data also provides information about the sources for fresh water. Students can analyze this data through graph-making exercises—ranking and graphing the raw volume of surface or ground water withdrawals, for example. Percentages (e.g., surface water is what percentage of total withdrawals?) can be calculated and then graphed. Assigning these graph-making exercises involves giving specific directions. To avoid confusion, write your graphing assignments on slips of paper and distribute them throughout the class. Students who do the same assignment can compare their results and a class-wide report can be compiled. Similar data on average precipitation amounts (also available from the U.S. Geological Survey) can be added to this analysis.

Figure 3 and Data Box 5 provide freshwater withdrawal data for 1990 in a format comparable to the 1985 data given on the poster. Because this data is more current, you may substitute it in the above activity. You may also ask students to compare the two data sets. How has water use changed over the five-year interval? Where has it changed the most? Where has it not changed? What hypotheses explain those differences and similarities? Again, you might ask students to produce a variety of graphs for comparison.

Extensions: Focus on particular states, especially your own. Where are the major sources of fresh water in your state? What water sources feed into your state's reservoirs? Are freshwater supplies in your state growing or shrinking? Who manages reservoirs and what are the long-term plans for guaranteeing continued supplies of fresh water? Ask students to investigate the major sources of freshwater withdrawal in your state. (This information is available in the *Estimated Uses of Water in the United States*. See the Resources List.)

Some states use more fresh water than is supplied by their own reserves. The remainder is obtained from neighboring states. Students can investigate this practice. What states do this? Why is their water demand so high? What are the regional effects of this practice? Who decides how much water can be sent out of a state? What kinds of technologies are required? Investigating this issue might prompt a student discussion of who "owns" the freshwater supplies in their community.

Activity Six
Let's Have Fun with Water

One key area of water use is recreation. In this activity, students investigate recreational water use, making estimates of the water used in different activities.

Begin this activity with a brainstorming session. Display the entire "Water: The Resource That Gets Used & Used & Used for Everything" poster so that your students can refer to it. Ask them to name ways fresh water (or salt water—but keep them separate) is used for recreation, using the poster to prompt rather than limit their brainstorming. Compile responses on the chalkboard and have students enter the completed list into their *Water Journals*. Take a poll to find out which recreational uses students most frequently do, then divide your class into "interest groups" to represent these uses. Ask each group to prepare a report on the skills, equipment, and local and national sites for these recreational activities. Ask them also to investigate the water use of that activity. How

much fresh water is required? (Swimming, for example, requires at least a pool full of fresh water.) Where does this fresh water come from? Where does it go afterwards? What sorts of changes were made to the water as a result of its use?

Activity Seven
Where Does the Water Go?

This activity focuses student attention on where water goes after it is used and introduces them to the poster, "How Do We Treat Our Wastewater?" Students track their own water use and brainstorm about what happens to that water after it is disposed of. Some of the basic water treatment systems also are introduced.

Ask students to examine the updated water use reports in their *Water Journals*. Estimate the quantity of fresh water used in their 24-hour interval using the "Water Use Chart" from the reverse side of the primary level poster, "Water: The Resource That Gets Used & Used & Used for Everything," and from your own calculations. Students should create pie charts to represent their water use and compare them with those of classmates. Show a transparency of the chart "Where You Use Water In Your Home" from the reverse side of the "How Do We Treat Our Wastewater?" poster. Ask them to copy this into their *Water Journals* and compare their own water use with the average use, summarized in that pie chart.

Once students develop a good sense for the volume and character of their water use, ask them the simple question: "Where did all that water go after it was used?" Begin a brainstorming session about the disposal of wastewater. List their responses on the chalkboard. After a few minutes, examine the replies. Initial responses most likely will include: "down the drain," "into the sewer," and similar general concepts. Prompt students to think further down the line by asking questions like "What does the drain flow into?" and "Where does the sewer go?" Ask them to write in their *Water Journals* a description of where they think wastewater goes after it is used. After several minutes of brainstorming, display "How Do We Treat Our Wastewater?" and ask your students to examine it.

To encourage closer study of wastewater treatment systems, divide your class into four groups and distribute two adjacent poster sections to each group. (Distributing sections that make up columns works best.) Ask them to follow wastewater through as many pathways as they can. How many kinds of pathways are represented? Make transparencies of the left column panels on the poster's reverse side (depicting the different system types). Show each transparency and ask students whether any of the types (e.g., septic tank, leach field, etc.) are represented in their poster sections. Tally the results as you proceed and be sure to locate each type of treatment on the poster so your whole class is introduced to these systems.

Extensions: Ask students to write a description of the path for one of the systems shown in their poster sections, e.g., from Peck's Apartments to the river. (If their entire system is not shown on their sections, they will need to consult the whole poster.) Treatment systems vary considerably across our nation. Ask your students to investigate what kind of system is used for their homes. Where does their wastewater go? Not all wastewater is treated in the same way. Water sprayed on lawns does not receive the same kind of treatment as water sent down the sink. Ask students to find out how many water treatment systems they have around their home or school.

Activity Eight
Taking the First Step: Modeling Primary Treatment

This activity demonstrates basic elements of primary wastewater treatment: filtration and settling. Students create models of these processes and run trials using sample "waste" water.

This activity is best done in small groups. Prepare by creating for each group a clear jar or jug (with lid) of sample "waste" water—a combination of dirt, small debris, and water. Be sure there is enough dirt so that sediments settle on the bottom of the container. To increase realism, add small pieces of trash, such as Styrofoam™, cardboard, or plastic chips. Create a series of three stations for each group or create one set for all groups to use. Each station should have a clean receiving container (2-liter plastic soft drink containers are ideal). After passing the "waste" water through each stage, students should write "before" and "after" observations in their *Water Journals*, making mention of what each stage collected, what passed through each stage, and how the cleaning process at that stage worked. Begin the exercise by asking students to record observations of the untreated "waste" water. What is in it? How clear is it? Where have they seen water like this before?

Caution note: Under no circumstances should your students drink any of the water samples, even after treatment. Warn them that *clear* water is not always *clean* water, and that they are learning about only *part* of the treatment process. Students should wash their hands after this experiment.

Mesh Screen Station

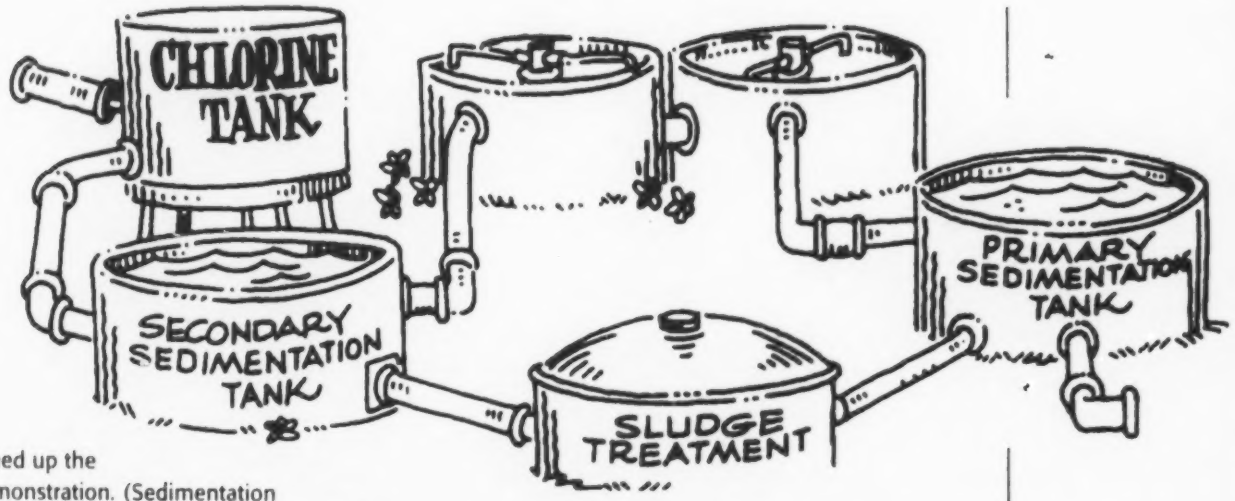
Use a mesh screen, with openings of approximately 2mm, as the first filter. Be sure students shake their "waste" water before starting so that the solids are in suspension. Be sure also that a container is placed underneath the filter to collect what passes through. (To facilitate observations in the second station, this receiving container should be clear.) This station represents the first filters in primary treatment. Save the material caught in the filter. Ask students how they would dispose of it. Is any of it recyclable? What would need to be done to make it sanitary, safe, and ready for reuse?

Settling Station

Move the container that received the filtered "waste" water to a location where it can be left undisturbed for approximately 10 minutes. Students should observe the settling process. What happens when the filtered water is left undisturbed for this time? (Placing a white background behind the container will make observations easier.) What is the purpose of a settling stage in water treatment? After the sample settles, students should slowly pour the wastewater into a new container, leaving the sediment behind. Students should record their observations about what passes onto the next station and what is left behind.

Fine Screen Station

Although additional sedimentation, not additional filtering, is the next stage of most treatment processes, filtering is used here to



speed up the demonstration. (Sedimentation can be substituted; samples left overnight show best results.) Use a nylon screen, filter paper, or other fine-grained film. As before, use a clear container to collect what passes through the filter. Observations should compare the "waste" water before and after it is passed through this filter. Students also should comment on what was caught in the filter.

After finishing the three stations, students should compare the "waste" water sample before and after the entire primary treatment process. What does primary treatment do? What happens to the material left in the filters? In wastewater treatment plants, the wastewater sent through these processes continues on for secondary treatment, where dissolved contaminants are removed.

Activity Nine
Water Treatment in Your Own Backyard

In this activity students investigate major wastewater treatment systems in their own community and develop a general map of wastewater treatment services for their area.

After discussing some of the different treatment systems, provide your students with copies of one of the investigation panels from the posters' reverse sides. (On the reverse of the middle level version, students investigate the treatment of their home's wastewater; on the reverse of the primary level version, students investigate treatment of their school's wastewater.) Ask students to complete the forms and collect additional information about local treatment systems. You probably will want to discuss research methods—such as using the telephone directory as a resource and how to locate contact people—with your students. Be sure to disperse research topics—consider the number of calls one facility may receive if *all* your students phone in the same week!

Ask your students to compile the results of their investigation into a short report. When these reports are completed, display a map of your community. (Topographic maps are available from the U.S. Geological Survey, most state geological surveys, and outdoor recreation suppliers. These maps also will be useful in studying wetlands.) Mark the locations of the wastewater treatment systems that serve your students' homes and the school. Does one system serve a large number of your students? Do the homes of any of your students use septic systems or other small-to-medium scale treatment systems? Is there a comprehensive plan for water treatment in your area? What local government oversees that plan? In their investigations, some of your students may have located maps—similar to what you are constructing—provided by area water commissions. If so, compare the two maps. What was missed in your class survey?

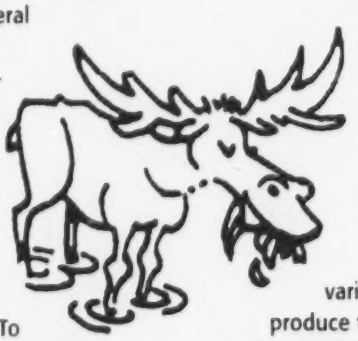
Extensions: Plan a trip to a water treatment facility in your community. Contact a public information representative from your area water and sanitation commission for information about tours.

Activity Ten
What Are Wetlands?

This activity introduces students to the poster "Wetlands: Water, Wildlife, Plants & People!" and to basic questions about wetlands: what are wetlands, where can they be found, and what lives in them. Students investigate particular wetland environments while developing an appreciation for the diversity of wetland types.

Begin with a brainstorming session by asking several questions: What are wetlands? Where are they? What can be found in them? (If familiar wetlands are nearby or if students have recently traveled through famous wetland areas, draw on that first-hand knowledge.) Record responses on the chalkboard, also have students keep a running list in their *Water Journals*. Have printed resources—books, magazine articles, pictures, and posters—distributed around the class to prompt ideas. (Single photographs or posters can provide an enormous amount of information.) As a variant, distribute resources describing different types of wetlands to different groups in your class and ask them to "represent" that wetland type in your introduction. Presenting a video, film, or filmstrip on wetlands (such as those produced by the National Geographic Society and the Audubon Society) provides strong visual images to supplement your discussion.

Through class discussion, summarize the basic conceptions developed by your students of what typical wetlands are, what is found in them, and where they are located. Display the "Wetlands: Water, Wildlife, Plants & People!" poster and allow students several minutes to examine it. More than a dozen wetland environments are represented. Divide your class into small groups and ask each group to investigate at least one of the wetland types. (Have the wetland names written on separate pieces of paper and select them for assignments.) To learn more about particular wetlands, each group should create a panel for part of a wetlands exhibit or a station for a wetlands investigation activity. Your available resources might lead you instead to focus on a single wetlands environment. In this case, groups of students can investigate different elements of that wetlands: plant life, animal life, soil and water, topography, human uses, and local lore. Many federal and state agencies provide detailed information about particular wetlands; see the Directory for contact information.



Extensions: Ask your students to write a creative story about life in a wetlands from some plant or animal's point-of-view. Direct students to describe a day, season, or year in that plant or animal's life. Or, have them write about a group of explorers working their way through a wetlands on the poster. What did they see? How did they move about? What would be in the report these explorers made to the people back home?

Activity Eleven
Where Are the Wetlands?

This activity helps students locate wetland areas within their own state and near their homes. Students also investigate the resources of their local wetlands.

In preparation for this activity, some research is required. Locate major wetland areas within your state and any wetlands near your school. If these areas are maintained by local, state, or federal agencies, call or write for information and maps of that area. Other resources—such as videos, pamphlets, or classroom visitors—might be available from these agencies, too.

Begin this activity by displaying or distributing maps of your state and of the region around your students' community. Laminated topographic maps (available from the U.S. Geological Survey, most state geological surveys or outdoor recreation suppliers) work best and usually are available in a variety of scales. Most states also produce tourist maps that highlight outdoor recreation; these are easily adapted for wetlands study. Contact your state's tourism board for more information.

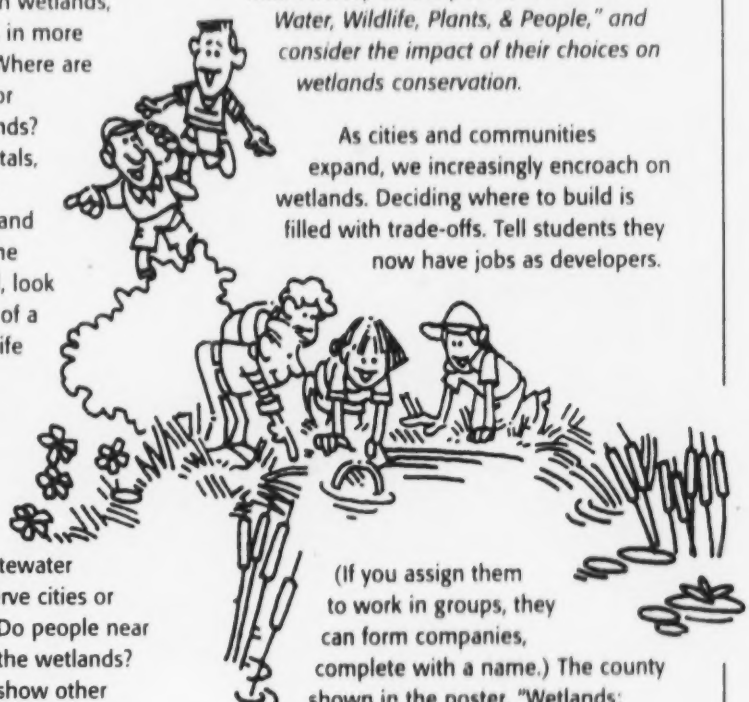
Be sure your students understand how to read a map before continuing. Also be sure students can locate key landmarks within their state (state capital, major terrain features and roads, their own location, etc.). Ask students to locate wetland areas within their state, recording in their *Water Journals* the locations, the general boundaries, and what kind of wetlands they've found. (You might divide the state into a number of sections and assign different sections to different groups.) Keep track of these identifications on a master list, which students should copy into their *Water Journals* when completed.

To investigate resources within wetlands, ask students to study their maps in more detail. First, look for recreation. Where are boat launches? fishing, hunting or scenic areas? parks? picnic grounds? Check phone books for boat rentals, guided tours, and private campgrounds in the area. Recreation and tourism are important parts of the economy in many areas. Second, look for wildlife. Is the wetlands part of a "protected" area, such as a wildlife refuge, preserve, or sanctuary? Check field guides to see if the area is home to endangered species or is along the flight path of migratory birds. Third, look for economic resources. Are freshwater reservoirs or wastewater treatment facilities–ones that serve cities or municipalities–located nearby? Do people near these areas make their living in the wetlands? What do they do? Do the maps show other resources or industries in the wetland area?

If you have difficulty locating suitable wetlands nearby, contact your state's soil or agricultural extension services, department of natural resources, or park service. Each can provide useful information for studying nearby wetlands. You might also contact local and national organizations concerned with natural history and conservation (e.g., the Audubon Society). As an alternative to wetlands in *your* state, focus on well-known, large-scale wetlands (Florida's Everglades, Maryland's Chesapeake Bay, Louisiana's bayou country, Utah's Great Salt Lake, or Washington's Puget Sound, for example). Some national parks and wildlife refuges are or include substantial wetland areas. The National Park Service and the U.S. Fish and Wildlife Service provide information and resources about these national treasures. Local libraries often maintain files with information about nearby wetlands.

Activity Twelve
Building Wetlands into Our Future

This activity uses role playing to teach interconnectivity. Students plan the location of a future library on the poster, "Wetlands: Water, Wildlife, Plants, & People," and consider the impact of their choices on wetlands conservation.



As cities and communities expand, we increasingly encroach on wetlands. Deciding where to build is filled with trade-offs. Tell students they now have jobs as developers. (If you assign them to work in groups, they can form companies, complete with a name.) The county shown in the poster, "Wetlands: Water, Wildlife, Plants, & People," needs a library built. As developers, your students need to choose a location for the library, together with a road connecting it to the school.

Their decision for the location needs to take into account many factors. They must minimize the impact on wetlands. The building must be in a convenient location, but also where people will want to visit. Some citizens in the county want to avoid overdeveloping one area (they don't want the library next to the school); others want to cluster development. Consider the alternatives. Also ask students to decide

where the road connecting the school to the library should be built. Their report should describe what impacts their choices will have on the surrounding environment, both by having the library (and the wastes generated there) nearby and by having people who visit the library also use the nearby land for picnics, car parking, and nature walks. What will each group do to minimize those impacts? Is there an area where they *absolutely* will not build on?

After the reports are submitted and presented to the class, hold a discussion comparing the various decisions. Students should see that *any* choice has positive and negative elements because of the interconnected nature of wetlands and the rest of our environment.

Extensions: Select a real building site located in a wetland area. Students can ask the questions listed above for this real case. If it is both convenient and safe to do so, students might visit the development to see, first hand, what took place. Developers, city managers, architects, or leaders of citizen groups can be invited to your class to discuss their views on the construction of this site and the steps taken to preserve wetland areas.

Let's Do More Research

Many additional research topics can be included in your water resources curriculum. This section provides topics for additional student assignments, science fair projects, and supplemental research.

More Water Use Research

Investigate water use in *your* community. Who uses the most water? What do they do with it? Who conserves the most water? What is the average water use for a house or apartment in your community? for a business? How effective are conservation programs in your community? What else can be done?

Investigate the sources of your school's water. How clean is the water? Is it treated

before you drink it? Who else uses this source for their fresh water? Has demand for your water increased or decreased over the last decade? If demand has increased, are your water reserves decreasing?

Investigate how your water supply is managed. Who manages it? How do they do it? Who "owns" the water before it arrives at your home? How much does tap water cost, how is it metered, and who gets the money you pay for it? Compare the price of tap water to other sources of fresh water, such as bottled water from a grocery store. Or, compare the price of water in other parts of the country and world.

Investigate indirect water use. Trace the manufacturing of a particular item and measure the amount of fresh water used in the process. For a loaf of bread, for example, ask: how much water is used to grow the grains for the flour? how much to refine the sugar? how much to culture the yeast? (Start from a recipe and work backwards.) Try items that are not food, too. How much water is required to create the electricity for running a 100-watt light bulb for one hour? How much water is used while manufacturing a ream of paper, an aluminum can, or a liter of paint?

If we used all our available fresh water, how would we get more? Investigate the process of manufacturing fresh water using processes such as desalinization or distillation. Would it be possible to tug icebergs to your community for use?

Investigate water use statistics in other countries and compare them with water use in the United States. Be sure to select countries in every part of the globe.

Investigate water conservation measures. Identify five actions that can be taken right *now* to conserve water. How much would these actions save? Design an advertising campaign to teach people about these measures.

More Wastewater Research

Investigate what happens to biosolids after they are removed during wastewater treatment. Are they disposed of or put to use? Where can they be used and where is their use prohibited?

Investigate the connection between wastewater and human diseases. What diseases are linked to wastewater and what are their symptoms? What in the wastewater causes these diseases? How does wastewater treatment remove these disease threats? Has there ever been a disease problem in your community linked to wastewater?

Some types of wastewater, such as radioactive waste, are not sent to regular treatment plants. Investigate what happens to them. Where do they go and what is done with them?

How much does wastewater treatment cost? Who pays this cost? What do the bills look like? Who receives the money from bills paid?

Investigate what can go wrong with treatment systems, especially septic tanks. Who maintains them? What should be done if these systems fail? What can your family or community do to help?

Investigate the microorganisms involved in treatment processes. What do they do? What do they look like? Where else do they live? Some plants and microorganisms absorb pollutants, such as excessive fertilizers and heavy metals, at considerable rates. Investigate their role in wastewater treatment.

Many industries must pretreat their wastewater before it is sent into municipal treatment systems. Investigate how a particular industry pretreats its wastewater. What is removed and what is not? Do you think this pretreatment is enough? What happens to the waste that is removed? Who monitors pretreatment to make sure it is effective?

More Wetlands Research

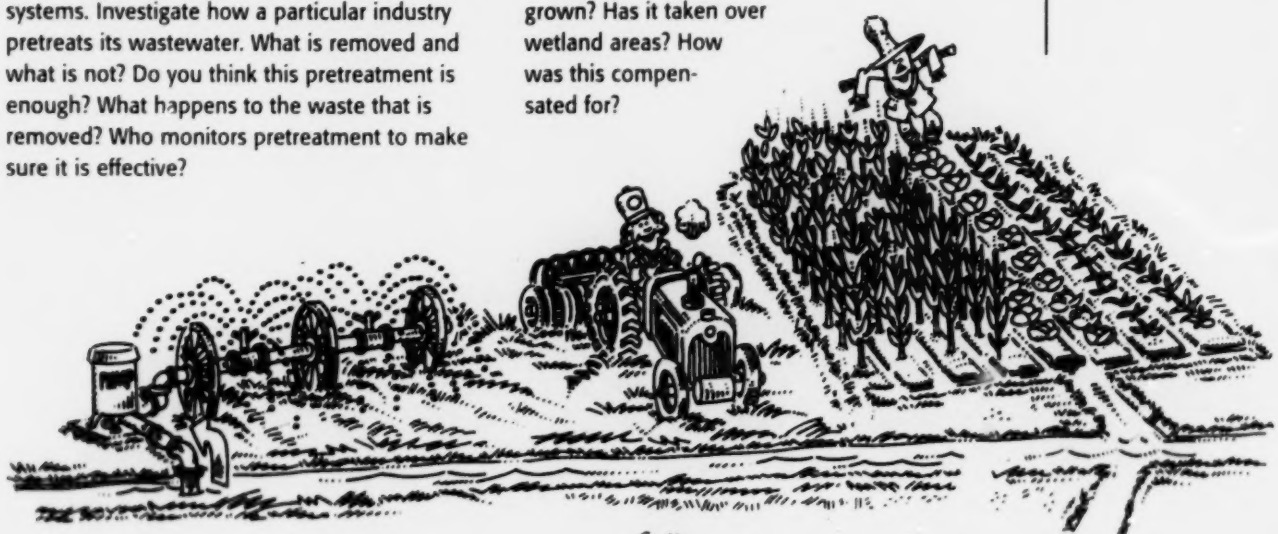
Investigate the history of wetlands in your state or region. How has the total area of wetlands changed over the past 50 or 100 years? What has happened to the areas that no longer are wetlands? How would you change land use to maintain wetlands in your area?

Wetlands play an important part in flood control by absorbing rising waters. Investigate the water-holding capacity of different soil types and combinations.

Investigate wetland ecosystems. These are complex biological communities, with a wide range of plant and animal life. Explore some of these creatures. Study their life stages and role in the wetland's ecosystem. Estuaries, such as the Chesapeake Bay, are highly productive biological communities; these make good choices for study.

Investigate the latest National Wetlands Inventory as it relates to your state. What does it report? What actions can you take to promote wetlands conservation? Investigate the federal laws and regulations regarding wetlands protection. In what ways are they too strict, too loose, or fair? How would you change them? Write to your local, state, and federal representatives to express your views.

Investigate the extent to which people live in wetland areas. Locate the 50 most populous cities in the United States. Where are they with respect to wetlands? Compare this with cities in other countries. Investigate the development of a nearby city. How has it grown? Has it taken over wetland areas? How was this compensated for?



Resources List

General Water Use

• Elaine Andrews and the Cooperative Extension National Review Team, *Educating Young People about Water: A Guide to Goals and Resources*, 1992. Surveys water resources curricula and topics. Guide to curriculum, activities, and related support material. Note on Internet resources.

Environmental Resources Center
216 Agriculture Hall
University of Wisconsin
Madison, WI 53706

• Jack Gartell, Jr., Jane Crowder, and Jeffrey Callister, *Earth: The Water Planet*, revised edition, 1992. Wide range of hands-on activities for water-related topics.

NSTA Publications and Sales
1840 Wilson Boulevard
Arlington, VA 22201-3000
(800) 722-NSTA

• Robert Mason and Mark Mattson, *Atlas of United States Environmental Issues*, 1990. Provides detailed information and data on water use and water-related subjects at both national and state levels.

Macmillan Publishing Company
4635 Hilton Corporate Dr
Columbus, OH 43232-4163
(800) 848-1567

• *Estimated Water Use in the United States in 1990*, U.S. Geological Survey Circular 1081, 1993. Extensive compilation of data on water use. Rich in statistics. Includes bibliography for data listed by state. (Report for 1985 is USGS Circular 1004.)

USGS, Book and Map Sales
12201 Sunrise Valley Dr.
Reston, VA 22092
(703) 648-6892

Directory

A variety of government agencies supply educational materials for water use, wastewater, and wetlands topics. So do many associations and private organizations. Consult your local telephone directory or public library for nearby offices. Or, write to your state delegate or representative to obtain contact information.

Federal Agencies

National Park Service
P.O. Box 37127
Washington, DC 20013-7127
(202) 208-4747

U. S. Department of Agriculture
Soil Conservation Service
Hotline
1-800-THE-SOIL

U. S. Environmental Protection Agency
Wetlands Hotline
1-800-832-7828

U. S. Fish and Wildlife Service
National Wetlands Inventory
9720 Executive Center Drive, Suite 101
St Petersburg, Florida 33702

U. S. Geological Survey
National Water Information Clearinghouse
423 National Center
Reston, VA 22092

Other Organizations

American Rivers
801 Pennsylvania Avenue, SE
Suite 400G
Washington, DC 20003-2167

American Water Resources Association
5410 Grovesnor Lane, Suite 220
Bethesda, MD 20814-2192

American Water Works Association
6666 West Quincy Avenue
Denver, CO 30235-3098

Freshwater Foundation
725 County Road 6
Wayzata, MN 55391-9611

Groundwater Federation
PO Box 22558
Lincoln, NE 68542-2558

National Audubon Society
666 Pennsylvania Ave, SE
Washington, DC 20003

Water Education Foundation
717 K Street, Suite 517
Sacramento, CA 95814-3408

Water Environment Federation
601 Wythe St.
Alexandria, VA 22314-1994

• National Geographic Society, "Special Edition: Water," *National Geographic*, November 1993. Entire issue of magazine devoted to water use issues. Includes useful maps. Companion videotape, "The Power of Water," sold by the Society. Other water use curriculum materials also available from Educational Services Department.

National Geographic Society
Educational Services Department
17th and M Streets NW
Washington, DC 20036
(301) 921-1330

Wastewater

• Water Environment Federation, *Wastewater Treatment: The Teacher's Resource Guide*, 1987. Intended for grades 7–9. Includes illustrations, activities, and lesson plans. *Student Resource Guide* also available.

Water Environment
Federation
601 Wythe Street
Alexandria, VA 22314
(703) 684-2400

• Steve Vandas, "How Do We Treat Our Wastewater," *Science and Children*, May 1992, pp. 18-19, and *Science Scope*, May 1992, pp. 26–28. Article accompanying poster in NSTA magazine. Includes additional activity.

either Managing Editor, *Science and Children*
or Managing Editor, *Science Scope*
National Science Teachers Association
1840 Wilson Boulevard
Arlington, VA 22201-3000
(703) 243-7100

• Douglas Zook (ed.), *The Microcosmos Curriculum Guide to Exploring Microbial Space*, 1992. Extensive middle-level curriculum for studying microorganisms, developing microscope techniques, and hands-on activities.

Kendall/Hunt Publishing Co.
2460 Kerper Boulevard, Box 539
Dubuque, IA 52004-0539
(800) 258-5622

Wetlands

• Britt Eckhardt Slattery, *WOW!: The Wonders of Wetlands*, 1991. Classroom and outdoor wetlands activities for K–12. Guide for hands-on fieldwork.

Environmental Concern Inc.
PO Box P
St Michaels, MD 21663
(410) 745-9620

• *Agriculture and Wetlands*, no date. Set of six fact sheets describing role of farmers and ranchers in wetlands protection and restoration.

U.S. Environmental
Protection Agency
Office of Wetlands,
Oceans, Watersheds
401 M St., SW
Washington, DC
20460

• *An Activity Guide for Teachers: Everglades National Park*, no date. Collection of grade 4–6 activities long-used by park educators. Content specific to south Florida; all activities are adaptable to local wetlands.

Environmental Education Office
Everglades National Park
PO Box 279
Homestead, FL 33030
(305) 242-7753

• *Mid Atlantic Wetlands: A Disappearing Natural Treasure*, no date. One of several regional studies. Summarizes current status and trends of wetlands in five-state region. Full of data, plus federal and state contact information.

U.S. Fish and Wildlife Service, Region 5
Fish and Wildlife Enhancement (NWI)
One Gateway Center
Newton Corner, MA 02158

• *The Wealth of Wetlands*, no date. Video featuring five farmers talking about wetlands and why they want to keep them. Available for loan.

National Association of Conservation Districts
PO Box 855
League City, TX 77574

The Author:

Sue Cox Kauffman is a consultant in environmental and Earth science education. For 10 years she taught Earth and life sciences at Webster Intermediate School in Webster, Texas. She currently lives in Red Lodge, MT.

In Memory of Richard A. Herbert

This *Teacher's Guide* is dedicated to the memory of Rich Herbert (1950-1994). Rich had a passion for water resources education. He served as Colorado's State Hydrologist for the U.S. Bureau of Land Management between 1978 and 1980. In 1980, Rich transferred to the U.S. Geological Survey, where he served with distinction in the Central Region's Denver office and in numerous districts (including Colorado, Louisiana, and Kansas).

Rich was extremely active in the national chapter of the American Water Resources Association (AWRA): he helped form the Louisiana section (serving as its first president) and was elected to the national board as a district director in 1985. Of his many accomplishments, Rich was most proud of his role developing the *Water Resources Education Initiative*. Rich was concerned about lackluster interest among Americans for water science and about the lack of attention to water resources issues in our schools. At his instigation, the *Initiative* was begun, originally as a joint AWRA/USGS program. It now has expanded to include the U.S. Environmental Protection Agency, the Army Corps of Engineers, the U.S. Fish and Wildlife Service, the Groundwater Federation, and the National Science Teachers Association.

Rich fully deserved the many awards and honors he received, including the 1991 Icko Iben Award for promoting communication among water resources disciplines and the AWRA president's Award for Outstanding Service in 1989. Rich died from cancer in March 1994. He is survived by two children, Jamie and Adam. We shall miss his skills, commitment, enthusiasm, and most of all, his friendship.

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